DISPENSING SYSTEM WITH A DIAPHRAGM METERING CHAMBER

I. BACKGROUND OF THE INVENTION

This invention relates to a liquid dispensing system and other devices which may be interchangeable and for dispensing small amounts of a liquid, such as a biological reagent, chemical reagent, or the like. The invention may include a liquid dispensing cartridge pump and methods for dispensing small amounts of liquids. It may also be applied specifically to automated systems for the pathology laboratory to perform special stains, immunohistochemical stains (IHC), or In Situ Hybridization (ISH).

It is understood that there are general methods for dispensing reagents in an automated system, including but not limited to, a repetitive non-disposable dispensing assembly design and a disposable dispensing assembly design. In one aspect, the repetitive non-disposable design may use pumps and tubing. This design may also be known as a "sip and spit". These devices draw fluid from a bottle through tubing (sip) and release the fluid onto the sample (spit). This design may be cost effective since the reagents may be packaged in the same bottles and long-term material compatibility issues may be minimized. Among the disadvantages of this design may be the continued maintenance to clean and flush the tubing to prevent carryover and cross contamination and that the reagents may be exposed to air which can reduce their useful shelf-life.

The disposable design generally may be understood to include a syringe pump assembly. This design may also be known as a "piston plunger". The disadvantages of this design may be that the force required to depress a plunger can vary significantly and piston plunger dispensers can be susceptible to leakage due to tolerance and material compatibility issues. The plunger may employ an elastomeric seal, which may contact the syringe barrel possibly providing a sliding or dynamic seal to retain the fluid. From one perspective, this design may be applicable only for a limited number of reagents and chemicals that are compatible with the elastomeric seal, but it may not be adequately useful for a broad range

of chemicals that may cause the seal to shrink or swell. However, the tolerances required for proper operation of this kind of seal can be difficult to achieve in standard manufacturing processes and it is at this interface that material compatibility concerns may have adverse effects possibly leading to leakage if the elastomer shrinks or binding if the elastomer swells.

U.S. Pat. No. 4,844,868 to Rokugawa, U.S. Pat. No. 5,232,664 to Krawzak et al., and U.S. Pat No. 6,045,759 to Ford et al., appear to have somewhat attempted to modify a form of a syringe pump. Each of these devices can draw fluid into a syringe through a check valve and may be dispensed through a second check valve. From one perspective, each of the disadvantages noted above for syringe pumps apply here as they may relate to tolerance and material compatibility concerns. In addition, the design noted in U.S. Pat. No. 6,045,759 appears to have the disadvantage that the vacuum created in the reagent reservoir should be released since the chamber may not be adequately collapsible. Some methods for vacuum release may be prone to blockage, tolerance issues, and may allow air to come in contact with the reagents. If air is in contact with a reagent, it may cause a decrease in the performance and stability of the reagent.

U.S. Pat. Nos. 5,645,114 and 5,316,452, both to Bogen et al. and U.S. Pat. Nos. 6,092,695 and 6,244,474 to Loeffler may include a liquid dispensing pump and a metering chamber attached to a liquid reservoir. While other items may have a syringe pump design, some items appear to have a compressible elastomeric metering chamber connected to a liquid reservoir and may include a flexible bag supported within a rigid housing. Among the disadvantages of these designs may include the following: the materials utilized for flexible bags may not be adequately robust and can be susceptible to punctures, sealing failures, and material compatibility issues; the materials utilized for flexible bags can be susceptible to breakage due to the rigors of shipping; the compressible metering chamber, made of an elastomer, may have the disadvantages of permeability, dimensional inaccuracy, and failures related to material incompatibility; the capacity of the metering chamber can be much larger than the desired dispense volume; and the volume of the fluid dispensed may be determined

by the dispensing mechanism on the automated system. Further, the accuracy of the dispenser can be significantly impacted by the calibration of a dispensing mechanism on an automated system.

Previous devices do not adequately address issues related to reagent stability, material incompatibility, vacuum created when drawing fluid from a liquid reservoir, shipping robustness, and dispense accuracy among others as in the present invention. In embodiments, an interchangeable liquid dispensing cartridge pump presented in this invention is one way to address some of these issues.

II. SUMMARY OF THE INVENTION

The present invention relates to a liquid dispensing system and other devices which allow for the dispensing of small amounts of liquids in an automated system.

In embodiments, the present invention may include a liquid metering chamber (32) that may accurately control the amount of fluid dispensed. In other embodiments, the amount of fluid may be controlled by the action of a diaphragm (33) or other flexible element, which may be assembled into a cavity of a dispenser housing (24). This may cause volumetric changes and may even create a metering chamber (32). A static seal may prevent leakage. The action of the diaphragm (33) may not be collinear or axially related to the reagent stream. The diaphragm action may be non-linear to the reagent stream. In another embodiment, the volume created by the metering chamber (32) may determine the volume of dispensed fluid. When the diaphragm (33) is compressed from its free or extended state to its inverted state, it may substantially conform to the inner surface of the metering chamber (32). This design may minimize the dead-volume of reagent and may assist in the priming process. The fluid may enter the metering chamber (32) through an upper unidirectional valve (34) or similar type element and may exit the dispenser housing (24) through a lower unidirectional valve or similar type element.

The lower unidirectional check valve assembly (25), as seen in figures 2 and 4 may attach to a dispenser housing (24). In some embodiments, the lower unidirectional check valve assembly (25) may include, but is not limited to, a lower valve disk (41), a lower valve retainer (42), and a lower valve membrane (43). The lower valve disk (41) may have a conical protrusion or other shape that may form a seal with the lower valve membrane (43). A valve seal may be formed between the protrusion on the lower valve disk (41) and an orifice on the lower valve membrane (43) because the protrusion on the lower valve disk (41) may deform the flexible lower valve membrane (43) and may keep it under tension. The elastic force of the lower valve membrane (43) may provide a positive fluid seal for the dispenser assembly. Fluid pressure may separate the lower valve membrane (43) from the lower valve disk (41) during the dispense cycle and the fluid may be expelled through the orifice in the lower valve membrane (43). The lower valve retainer (42) may allow the attachment of the lower unidirectional check valve assembly to the dispenser housing (24). The lower valve retainer (42) may form a seal between the lower valve membrane (43) and the dispenser housing (24).

A novel dual use clamp may attach the dispenser housing (24) to the liquid reservoir and may register the dispenser onto the automated system. The clamp may include, but is not limited to, a left clamp (12) and a right clamp (13), as seen in figure 1. In an embodiment, the reagent reservoir may consist of a collapsible molded bottle. The connection or connections between a bottle and a dispenser housing (24) may be sealed by either or both radial and flange seals or the like. In another embodiment, as shown in figure 2, the present invention may use a radial o-ring seal (21) and a flange o-ring seal (22) to create a seal between the reservoir or bottle and the dispenser housing (24). The vacuum created by the compression and release of the diaphragm (33) may draw the fluid from the reagent reservoir into a metering chamber (32) through an upper unidirectional check valve. A precise volume of fluid may be drawn from the reservoir and dispensed from a dispenser housing assembly through a lower unidirectional valve during the dispense cycle. The vacuum that may be built up inside the reservoir from the dispensing of fluid may not need to be released due to the fact that the reservoir may include a collapsible bottle. The force

required to collapse the bottle may be less and may even be significantly less than that required to compress and return the diaphragm (33) and dispense the fluid.

The liquid dispensing cartridge pump in embodiments of the invention may include a dispenser assembly (14) attached to a liquid reservoir or a collapsible reservoir (51). In an embodiment, the dispenser assembly (14) may consist of a molded diaphragm assembly inserted into a dispenser housing (24) and may even form a metering chamber (32).

Opposite a metering chamber (32) and attached to the dispenser housing (24) may be a unidirectional valve or the like element. At the bottom of the dispenser housing (24), a second unidirectional valve assembly, or the like element, may be attached. The assembly may utilize a disk that may even serve the dual purpose of a sealing surface and a flow director.

The mechanism of attachment for the dispenser assembly (14) and fluid reservoir may serve at least two purposes. It can clamp the liquid reservoir to the dispenser housing (24) and may even provide a mounting feature for location on an automated system. Elastomeric o-rings or the like element may be used in either or both a radial and flange configuration at an interface between a liquid reservoir and a dispenser housing (24) to prevent fluid leakage.

In embodiments, the liquid reservoir may include a collapsible plastic molded bottle. The material properties of this bottle may be highly compatible with most chemical and biological reagents. The material and thickness of the bottle may be such that evaporation and permeability are minimized while at the same time may even allow for the bottle to collapse due to the vacuum created from the withdrawal of fluid. The forces required to collapse the bottle can be less and may even be significantly less than the forces provided by the diaphragm assembly. The diaphragm assembly can return to its uncompressed or free state with the assistance of a compression element, such as a spring or the like element. The liquid reservoir may be encapsulated by a housing, such as a two-piece housing or the like.

Of course, the housing may be any number of pieces. The housing may serve to provide a surface for identification by either the automated instrument or the user. It may also provide protection and support for the reservoir.

In some embodiments, the diaphragm assembly may consist of at least a plastic molded diaphragm (33), a compression spring (31) and a dispense plunger (23). The dispense plunger (23) may be snapped onto the molded diaphragm (33). The material for the molded diaphragm (33) may have similar properties as that for the liquid reservoir. The diaphragm assembly may be placed in a cavity in a dispenser housing (24) forming a metering chamber (32). The diaphragm (33) may form a static seal against the dispenser housing (24) when a retainer, or the like element, and an elastomeric o-ring, or the like element, may be snapped into position against the outside of the diaphragm (33). Further, in embodiments, the fluid may be moved through the metering chamber (32) without any sliding parts. The fluid may simply be dispensed with non-sliding parts or may even be dispensed with reduced friction. Sliding parts may create friction, as it may be understood to occur in the syringe pump design. The disadvantages, such as the elastomer to chemical reagent incompatibility and elastomeric seal to syringe barrel tolerance concerns may be eliminated since the fluid seal is static in this embodiment.

III. BRIEF DESCIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not all to scale but are intended to illustrate the principles of the invention.

Figure 1 shows an embodiment of the invention of a liquid dispensing cartridge pump assembly including:

Reservoir Assembly (11)

Left Clamp (12)

Right Clamp (13)

Dispenser Assembly (14)

Figure 2 shows a partial view of an embodiment of the invention of a dispenser assembly including:

Radial O-Ring Seals (21)

Flange O-Ring Seal (22)

Dispense Plunger (23)

Dispenser Housing (24)

Lower Unidirectional Valve Assembly (25)

Figure 3 shows a sectional view of an embodiment of a dispenser assembly including:

Dispenser Housing (24)

Compression Spring (31)

Metering Chamber (32)

Diaphragm (33)

Dispense Plunger (23)

Upper Unidirectional Valve (34)

Narrow Channel (35)

Figure 4 shows a sectional view of an embodiment of a lower unidirectional valve assembly including:

Lower Valve Disk (41)

Lower Valve Retainer (42)

Lower Valve Membrane (43)

Figure 5 shows a partial view of an embodiment of a reservoir assembly including:

Collapsible Reservoir (51)

Right Reservoir Housing (52)

Note: The left reservoir housing is not shown in this picture

Figure 6a shows a sectional view of an embodiment of the diaphragm in the free state.

Figure 6b shows a sectional view of an embodiment of the diaphragm in the compressed state.

IV. DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As mentioned earlier, the present invention includes a variety of aspects, which may be combined in different ways. The following descriptions are provided to list elements and describe some of the embodiments of the present invention. These elements are listed with initial embodiments, however it should be understood that they may be combined in any manner and in any number to create additional embodiments. The variously described examples and preferred embodiments should not be construed to limit the present invention to only the explicitly described systems, techniques, and applications. Further, this description should further be understood to support and encompass descriptions and claims of all the various embodiments, systems, techniques, methods, devices, and applications with any number of the disclosed elements, with each element alone, and also with any and all various permutations and combinations of all elements in this or any subsequent application.

In an embodiment, the present invention may include a reservoir assembly (11) in which the reagent may be contained. The reservoir assembly may include a reservoir housing (52) and a collapsible reservoir (51).

To prime the metering chamber (32), the plunger diaphragm assembly may be compressed and released. The compression of the plunger (23) may be accomplished by either manual method or automation means. A user of the reagent cartridge could depress the plunger with a finger or thumb to prime the system initially. An automated system could use a number of devices to compress the plunger such as, but not limited to a stepper/servo motor, an air cylinder, or the like element. In embodiments, the plunger diaphragm assembly may be primed or used by compressing the plunger and releasing the plunger. This may be accomplished by manual operation or even by automated operation.

In an embodiment, the present invention may allow priming with the tip facing down. Other designs may require priming with the tip facing up which may expose the user to potential hazardous material that may be contained in the reagent reservoir. The present invention may provide little or negligible amounts of air that can be trapped in the system. In embodiments, the shape of the diaphragm (33) may match or even closely match the contour of the inner surface of the dispenser housing (24) when the diaphragm (33) is compressed using the method described above. This design may force any trapped air through a narrow channel (35), which may be formed in the dispenser housing (24), and out of the lower unidirectional valve. The narrow channel may minimize a dead volume of reagent chemistry. Dead volume may be the volume that is not directly contained in the metering chamber (32) and may not be expelled during the priming and/or normal dispense operation. The narrow channel (35) may minimize the amounts of reagent or liquid not directly contained in the metering channel.

In an embodiment, the vacuum created inside the metering chamber (32) when the diaphragm (33) is returned to its free state may open up an upper unidirectional valve (34). The fluid from the liquid reservoir may flow into the metering chamber (32). The dispenser may be self-priming because there is little dead-volume in the metering chamber (32) and the shape of the cavity in the dispenser housing (24) may closely match the shape of the diaphragm (33) in the extended state.

As shown in figure 6b, each time the diaphragm (33) is compressed, an equal volume of fluid may be drawn from the reservoir and dispensed from the dispenser housing (24) through the lower unidirectional check valve. The compression spring (31) may overcome the vacuum formed inside the liquid reservoir to return the diaphragm (33) to its free state, as shown in figure 6a. The accuracy and consistency of the dispensed fluid may be tightly controlled due to the fact that the metering chamber volume remains the same. The spring (31) can return the diaphragm (33) to an internal mechanical stop in its free state and the compressed state of the diaphragm (33) may be controlled by the inner surface of the dispenser housing (24). Accurate and repeatable dispense volume can be critical for an automated system. The requirements and justification for an automatic system may be consistency across a multitude of tests and operations. The present invention may be less susceptible to variations and tolerances than other presently available dispensing apparatus utilizing the disposable dispensing assembly design approach.

The present invention may extend the usable shelf life of the chemistry stored in the liquid reservoir due to the fact that air is not introduced into the system during the dispensing process and may even be a non-air exposing system. Other dispensing systems may require the release of vacuum, which is created as the fluid is evacuated from the reservoir. Further, other designs may utilize a valve or vented cap. The collapsible bottle design in embodiments of the present invention may not require air introduction.

In embodiments, the flexible liquid reservoir may be molded from a polyolefin material, or the like materials. Other flexible liquid reservoirs are made from a film material, which is then manufactured into a bag. Bags may be manufactured using unreliable sealing methods to form the container. The seal formed during the heat and compression manufacturing method can be susceptible to voids, holes, and non-uniformity. From one perspective, molding the flexible reservoir may be cost effective, reliable, and uniform. Polyolefin material may be inert to most chemicals due to its homogeneity nature. The material properties of the polyolefin may also provide a high modulus of elasticity that may minimize the forces required to collapse a reservoir.

Further, in other embodiments, a reservoir housing may be used to contain the reservoir. The reservoir housing may include, but is not limited to, a left reservoir housing and a right reservoir housing (52), as shown in figure 5. The reservoir housing may provide a surface for identification by either the automated instrument or the user. It may also provide protection and support for the reservoir.

In an embodiment, the end of travel for the diaphragm (33), which may be part of the metering chamber (32), may be controlled by a hard stop. This feature can eliminate the need for calibration of this assembly. Other designs may require the travel of the actuation device, for example, stepper/servo motors, air cylinders, and the like, to be calibrated to account for mechanical tolerances, which may be introduced as part of the assembly process. With this invention, the dispensed volume can remain consistent from position to position within an automated instrument or between multiple instruments. Dispense volume repeatability can be critical for consistent sample processing on the automated system.

As mentioned earlier, in another embodiment, the present invention may provide for tip down priming. Other designs may require the tip to be facing up so that air bubbles that may be trapped are released to the top. The air bubbles may be then evacuated by drawing them out with a syringe or other means. The use of an additional syringe may be both complicated and costly. Tip up priming may be inherently unsafe and can even require additional precautions to prevent harmful contact with the chemical being primed.

In embodiments, the design of the metering chamber (32) may allow for the use of a shipping lock. This feature may hold the diaphragm (33) in the compressed position. A feature or element on the diaphragm (33) may be positioned to contact the upper unidirectional valve (34) and may prevent the flow of reagent into the metering chamber (32). This unique and novel feature may serve two purposes. It may increase the shelf life of the product and it may prevent fluid from dripping during shipping.

The flexible diaphragm utilized in an embodiment of the present invention may be unique in that it may provide a flexible membrane that is chemically resistant and may also contain features to allow it to connect to the dispense plunger (23). Other flexible chemically resistant diaphragms may either be made from a sheet of plastic and do not adequately have mounting features or are made out of a plastic and rubber composite that may contain either an inserted plastic or metal feature to connect to the dispense mechanism. Again, as mentioned earlier, in an embodiment of the present invention, polyolefin material may be used and may be inert to most chemicals due to its homogeneity nature. The material properties of the polyolefin material used for the manufacture of the diaphragm (33) may also provide a high modulus of elasticity that minimizes the forces required to compress it.

As can be easily understood from the foregoing, the basic concepts of the present invention may be embodied in a variety of ways. It involves both dispensing techniques as well as devices to accomplish the appropriate dispenser. In this application, the dispensing techniques are disclosed as part of the results shown to be achieved by the various devices described and as steps which are inherent to utilization. They are simply the natural result of utilizing the devices as intended and described. In addition, while some devices are disclosed, it should be understood that these not only accomplish certain methods but also can be varied in a number of ways. Importantly, as to all of the foregoing, all of these facets should be understood to be encompassed by this disclosure.

The discussion included in this provisional application is intended to serve as a basic description. The reader should be aware that the specific discussion may not explicitly describe all embodiments possible; many alternatives are implicit. It also may not fully explain the generic nature of the invention and may not explicitly show how each feature or element can actually be representative of a broader function or of a great variety of alternative or equivalent elements. Again, these are implicitly included in this disclosure. Where the invention is described in device-oriented terminology, each element of the device implicitly performs a function. Apparatus claims may not only be included for the device described, but also method or process claims may be included to address the functions the

invention and each element performs. Neither the description nor the terminology is intended to limit the scope of the claims which will be included in any subsequent patent application.

It should also be understood that a variety of changes may be made without departing from the essence of the invention. Such changes are also implicitly included in the description. They still fall within the scope of this invention. A broad disclosure encompassing both the explicit embodiment(s) shown, the great variety of implicit alternative embodiments, and the broad methods or processes and the like are encompassed by this disclosure and may be relied upon when drafting the claims for any subsequent patent application. It should be understood that such language changes and broader or more detailed claiming may be accomplished at a later date (such as by any required deadline) or in the event the applicant subsequently seeks a patent filing based on this filing. With this understanding, the reader should be aware that this disclosure is to be understood to support any subsequently filed patent application that may seek examination of as broad a base of claims as deemed within the applicant's right and may be designed to yield a patent covering numerous aspects of the invention both independently and as an overall system.

Further, each of the various elements of the invention and claims may also be achieved in a variety of manners. This disclosure should be understood to encompass each such variation, be it a variation of an embodiment of any apparatus embodiment, a method or process embodiment, or even merely a variation of any element of these. Particularly, it should be understood that as the disclosure relates to elements of the invention, the words for each element may be expressed by equivalent apparatus terms or method terms -- even if only the function or result is the same. Such equivalent, broader, or even more generic terms should be considered to be encompassed in the description of each element or action. Such terms can be substituted where desired to make explicit the implicitly broad coverage to which this invention is entitled. As but one example, it should be understood that all actions may be expressed as a means for taking that action or as an element which causes that action. Similarly, each physical element disclosed should be understood to encompass a

disclosure of the action which that physical element facilitates. Regarding this last aspect, as but one example, the disclosure of a "retainer" should be understood to encompass disclosure of the act of "retaining" -- whether explicitly discussed or not -- and, conversely, were there effectively disclosure of the act of "retaining", such a disclosure should be understood to encompass disclosure of a "retainer" and even a "means for retaining. Such changes and alternative terms are to be understood to be explicitly included in the description.

Any patents, publications, or other references mentioned in this application for patent are hereby incorporated by reference. In addition, as to each term used it should be understood that unless its utilization in this application is inconsistent with such interpretation, common dictionary definitions should be understood as incorporated for each term and all definitions, alternative terms, and synonyms such as contained in the Random House Webster's Unabridged Dictionary, second edition are hereby incorporated by reference. Finally, all references listed in the list of References To Be Incorporated By Reference In Accordance With The Provisional Patent Application or other information statement filed with the application are hereby appended and hereby incorporated by reference, however, as to each of the above, to the extent that such information or statements incorporated by reference might be considered inconsistent with the patenting of this/these invention(s) such statements are expressly not to be considered as made by the applicant(s).

Thus, the applicant(s) should be understood to have support to claim and make a statement of invention to at least: i) each of the dispenser devices as herein disclosed and described, ii) the related methods disclosed and described, iii) similar, equivalent, and even implicit variations of each of these devices and methods, iv) those alternative designs which accomplish each of the functions shown as are disclosed and described, v) those alternative designs and methods which accomplish each of the functions shown as are implicit to accomplish that which is disclosed and described, vi) each feature, component, and step shown as separate and independent inventions, vii) the applications enhanced by the various systems or components disclosed, viii) the resulting products produced by such systems or

components, ix) each system, method, and element shown or described as now applied to any specific field or devices mentioned, x) methods and apparatuses substantially as described hereinbefore and with reference to any of the accompanying examples, xi) the various combinations and permutations of each of the elements disclosed, and xii) each potentially dependent claim or concept as a dependency on each and every one of the independent claims or concepts presented.

With regard to claims whether now or later presented for examination, it should be understood that for practical reasons and so as to avoid great expansion of the examination burden, the applicant may at any time present only initial claims or perhaps only initial claims with only initial dependencies. Support should be understood to exist to the degree required under new matter laws -- including but not limited to European Patent Convention Article 123(2) and United States Patent Law 35 USC § 132 or other such laws-- to permit the addition of any of the various dependencies or other elements presented under one independent claim or concept as dependencies or elements under any other independent claim or concept. In drafting any claims at any time whether in this application or in any subsequent application, it should also be understood that the applicant has intended to capture as full and broad a scope of coverage as legally available. To the extent that insubstantial substitutes are made, to the extent that the applicant did not in fact draft any claim so as to literally encompass any particular embodiment, and to the extent otherwise applicable, the applicant should not be understood to have in any way intended to or actually relinquished such coverage as the applicant simply may not have been able to anticipate all eventualities; one skilled in the art, should not be reasonably expected to have drafted a claim that would have literally encompassed such alternative embodiments.

Further, if or when used, the use of the transitional phrase "comprising" is used to maintain the "open-end" claims herein, according to traditional claim interpretation. Thus, unless the context requires otherwise, it should be understood that the term "comprise" or variations such as "comprises" or "comprising", are intended to imply the inclusion of a stated element or step or group of elements or steps but not the exclusion of any other

element or step or group of elements or steps. Such terms should be interpreted in their most expansive form so as to afford the applicant the broadest coverage legally permissible.

Finally, any claims set forth at any time are hereby incorporated by reference as part of this description of the invention, and the applicant expressly reserves the right to use all of or a portion of such incorporated content of such claims as additional description to support any of or all of the claims or any element or component thereof, and the applicant further expressly reserves the right to move any portion of or all of the incorporated content of such claims or any element or component thereof from the description into the claims or vice-versa as necessary to define the matter for which protection is sought by this application or by any subsequent continuation, division, or continuation-in-part application thereof, or to obtain any benefit of, reduction in fees pursuant to, or to comply with the patent laws, rules, or regulations of any country or treaty, and such content incorporated by reference shall survive during the entire pendency of this application including any subsequent continuation, division, or continuation-in-part application thereof or any reissue or extension thereon.